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STINKING SMUT (BUNT) IN WHEAT AND HOW TO PREVENT IT

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INTRODUCTION

The farmers who can grow the best wheat at the least expense can continue to produce the crop at a profit even in times of low prices. One of the easiest and most promising ways of making the crop more profitable is by controlling stinking smut (bunt). It was estimated [1] that in 1927 stinking smut caused a reduction in yield of wheat in the United States amounting to 28,888,000 bushels, or an average of about one-half bushel per acre harvested. Added to this were the discounts for smutty wheat on the market, which undoubtedly amounted to several millions of dollars. These losses could have been prevented by seed treatment at a cost of from 5 to 10 cents an acre.

Stinking smut is one of the most common and most important wheat diseases. Being closely associated with the seed, and having the same climatic requirements as wheat itself, it has spread and established itself practically everywhere the crop is grown. It occurs generally throughout the United States except possibly in a few communities or local areas where united efforts have been put forth to eradicate it.

Weather conditions, time of planting, amount and kind of seed treatment, and possibly other factors influence its prevalence. For several years it may be of only moderate importance in a State or area, and then for a year or a period of years it may become outstandingly important. Prior to 1924 it had attracted but slight attention in Kansas, but during that year, and also in 1925 and 1926,

[1] United States Department of Agriculture, Bureau of Plant Industry. crop losses from plant diseases in the united states in 1927. U. S. Dept. Agr., Bur. Plant Indus. Plant Disease Rptr. Sup. 64: 371. 1928. [Mimeographed.]

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it caused losses estimated at 8, 6, and 10 per cent of the crop, respectively. In Pennsylvania and other Eastern States there was a very marked increase in severity in 1925, 1926, and 1927. In the spring-wheat States there has been a decided increase in severity since about 1925. Previous to that year the percentage of carloads of hard red spring and durum wheat grading smutty at Minneapolis had been averaging only from 1 to 2 per cent. Commencing in 1925, however, and continuing in 1926, 1927, 1928, 1929, and 1930, the receipts averaged 16.4, 11.7, 11.1, 14.9, 12.6, and 17.8 [2] per cent, respectively. Coincident with this was an increase of smut in durum wheat, which until that time had been, on the whole, rather free from smut. Investigations have pointed to the possibility that this increase may have been due to the introduction and spread in durum wheats of one or more new physiological forms or races of stinking smut.

In spite of the fact that stinking smut is readily suppressed by proper and well-known seed-treatment methods, and theoretically should be on the decline as these methods become more generally adopted, the disease continues as a cause of heavy annual losses, and, in some areas at least, is on the increase rather than on the decrease.

LOSSES FROM STINKING SMUT

Stinking smut is important (1) because it reduces yields, sometimes very greatly, and (2) because it blackens and odorizes the grain, making it unsatisfactory for milling until the smut is removed by washing or scouring. This necessitates an additional cost and is reflected in a lower price of wheat to the farmer.

A smutted head is a total loss. Experiments [3] have shown that the percentage of smutted heads in the field is approximately the same as the actual loss in yield to the farmer. A field with 25 per cent of the heads smutty will show a reduction in yield of about one-fourth on account of smut.

During the summer of 1930 counts to determine the amount of stinking smut were made in 704 spring-wheat fields in 16 counties in Minnesota, the Dakotas, and Montana. The average amount of smut found in all fields was 2.8 per cent. If this is considered as the average for all four States—and probably it is not far from correct—it represents a reduction in yield of 5,138,000 bushels of spring wheat. At 78 cents a bushel this quantity of wheat would be worth about $4,000,000. During the period 1917 to 1927 the Bureau of Plant Industry issued annual estimates [4] of the reduction in yield of certain crops from plant diseases. The average annual loss from stinking smut of wheat over that 11-year period was 2 per cent, and the average annual reduction in yield was 18,000,000 bushels.

Smutty wheat can not command as high a price as clean wheat when sold on the market. Many mills refuse to buy it. Others that are equipped with washing and scouring apparatus can use smutty wheat, but naturally will not pay as high a price for it as if it were

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[2] Percentages are for crop years, July 1 to June 30.

[3] HEALD, F. D., and GAINES, E. F. THE CONTROL OF BUNT OR STINKING SMUT OF WHEAT. Wash. State Agr. Expt. Sta. Bul. 241: 16–17. 1930.

[4] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF PLANT INDUSTRY. CROP LOSSES FROM PLANT DISEASES. U. S. Dept. Agr., Bur. Plant Indus. Plant Disease Rptr. 2, and Sup. 6, 12, 18, 24, 30, 36, 43, 49, 56, and 64. 1918–1927. [Mimeographed.]

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clean. In the case of spring wheat, cars grading smutty may be discounted from $45 to $250 or even more per car, depending on whether the amount of smut is classified as "light," "medium," or "heavy." The grain trade east of the Rocky Mountains uses a grading system which designates wheat containing smut as "smutty," and in many markets the smutty condition is further indicated by a special designation such as either "light," "medium," or "heavy" smut. The grain trade on the Pacific coast designates the degree of smut in grain in terms of one-half per cent by weight. A large proportion of these losses are passed back to the grower either directly in the form of a discount or indirectly through a correspondingly lower price paid at the elevators to producers of clean and smutty wheat alike. The average discount for smutty spring wheat of the 1930 crop at country elevators was about 5 cents a bushel.

During the crop year 1929 a total of 596,559 cars of wheat were received at 155 markets at which Federal supervised grain inspection service is performed. Of these cars, 68,285, or 11.4 per cent of the receipts, amounting to approximately 102,427,500 bushels, graded smutty. (Table 1.)

TABLE 1.—*Carloads of wheat grading smutty, as shown by licensed inspection of receipts at 155 terminal markets for the crop year July 1, 1929, to June 30, 1930*

Class of wheat	Total carloads inspected	Carloads smutty	Per cent smutty
Hard red spring	94,829	5,331	5.6
Durum	25,261	4,987	19.7
Hard red winter	361,898	41,382	11.4
Soft red winter	43,992	2,632	6.0
White	31,160	6,956	22.3
Mixed (including mixed durum)	39,419	6,997	17.8
Total	596,559	68,285	11.4

HOW TO RECOGNIZE STINKING SMUT IN THE FIELD

Although the wheat plant becomes infected when it is a very young seedling and even before it appears above the ground, infected shoots (culms) can not be distinguished from healthy ones until the heads appear. Immediately after blooming the yellow pollen sacs or anthers emerge and dangle from the healthy heads but are entirely absent in the totally infected heads. About the time the wheat is in the dough stage the infected heads assume a bluish-green color in contrast to the lighter green of the healthy ones. They also remain green longer than the sound heads. In varieties in which the normal heads bend over slightly with the weight of the kernels the smutty heads are noticeably erect. In some varieties, especially club wheat, the smutty heads are more slender and often longer than the sound heads. Infected culms on the average are shorter than the healthy ones.

As the grain ripens the smutty heads can be distinguished by the spreading of the chaff (glumes) and the appearance of the dark smut balls protruding from between them. In bearded varieties the beards (awns) are often deformed and brittle. When the grain is fully ripe the glumes of the diseased heads assume a pale, ashen color instead of the slightly golden yellow of the healthy heads.

In some varieties the smutted heads are not easily distinguished. This applies especially to the durum wheats. The smut balls may be easily crushed between the fingers into an oily black mass which gives off a disagreeable fishy odor. In a single plant all or only part of the heads may be smutty. In a single head all the kernels may be diseased or only part of them and the rest may be sound. Smutty and healthy heads are shown in Figures 1 and 2.

FIGURE 1.—Normal and smutted heads and kernels of wheat: A, Healthy head and kernels; B, head affected with stinking smut, and smut balls, those in the lower group being cut into halves

Stinking smut is easily distinguished from the loose smut of wheat, which appears at the time of flowering as a naked, fluffy, black mass.

Loose-smut heads have no covering and the smut is soon blown or washed away, leaving a bare stalk. This disease can be controlled only by the hot-water treatment. In general it is of less importance than stinking smut. (Fig. 2.)

HOW TO RECOGNIZE STINKING SMUT IN THE THRESHED GRAIN

In the threshed grain the presence of stinking smut may be recognized (1) by the distinctly fishy odor which is given off by the smut, (2) by the presence of whole and broken smut balls, and (3) by smut pores which adhere to the wheat kernels and give a dark color to the wheat, especially if it is very smutty.

If wheat is stored in a well-ventilated place the odor becomes less pronounced after a period of weeks or months, so that the presence of smut may not always be detected by this means. But the presence of smut balls in the grain is always a positive indication of infestation. These smut balls are shaped somewhat like wheat kernels but as a rule are shorter and proportionately more plump. (Fig. 3.) They vary in color from silvery gray to light brown. The smut balls are creased like wheat kernels, but are without the hairy "brush" found on wheat kernels. As stated

before, they may be easily crushed between the fingers into a slightly oily, black mass of ill-smelling powder or spores.

A single smut ball contains from 2,000,000 to 4,000,000 spores. Each spore is capable of infecting a wheat plant unless it is removed from the seed or its viability is destroyed by treatment.

In heavily smutted wheat the kernels have smut spores adhering to all parts of their surfaces, giving the grain a dark color.

In more lightly smutted grain the spores are most abundant at the hairy brush end of the kernel and in the crease. If all the balls have been removed from rather lightly smutted wheat, the presence of the spores on the kernels is not always readily detected. The

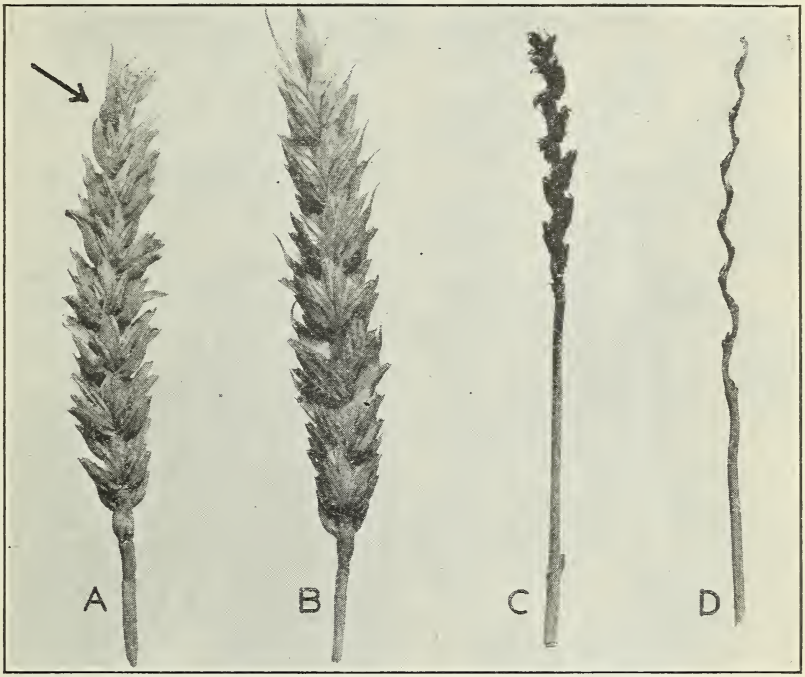

FIGURE 2.—Stinking smut (A, B) and loose smut (C, D) of wheat: A, Head affected with stinking smut; arrow points to spikelet with glumes removed to show smut ball; B, healthy head of same variety; C, loose smut, same variety, mature stage; D, loose smut, same variety, late stage

wheat may even be judged smut free and yet may carry enough spores to produce a heavily infected crop if the soil and climatic conditions are favorable. An examination of such kernels under the microscope will reveal the presence of smut spores.

When wheat is sold on the market it is always examined for smut. The Federal standards (grades) for wheat specify that—

> Smutty wheat shall be all wheat which has an unmistakable odor of smut, or which contains spores, balls, or portions of balls of smut in excess of a quantity equal to two balls of average size in 50 grams [approximately 2 ounces] of wheat.

Smutty wheat is discounted in price. The Federal standards permit commercial grain to contain up to two balls of smut in 50 grams

of the wheat and still be classified as smut-free wheat. Seed wheat, however, would be considered to be heavily infested with smut if it contained as much as two balls of smut or its equivalent in spores and pieces of balls in 50 grams of wheat.

HOW TO PREVENT STINKING SMUT

Serious losses from stinking smut, either from reduced yields of grain or from reduced prices at the elevators and mills, can be prevented, especially in regions where soil infestation does not occur.

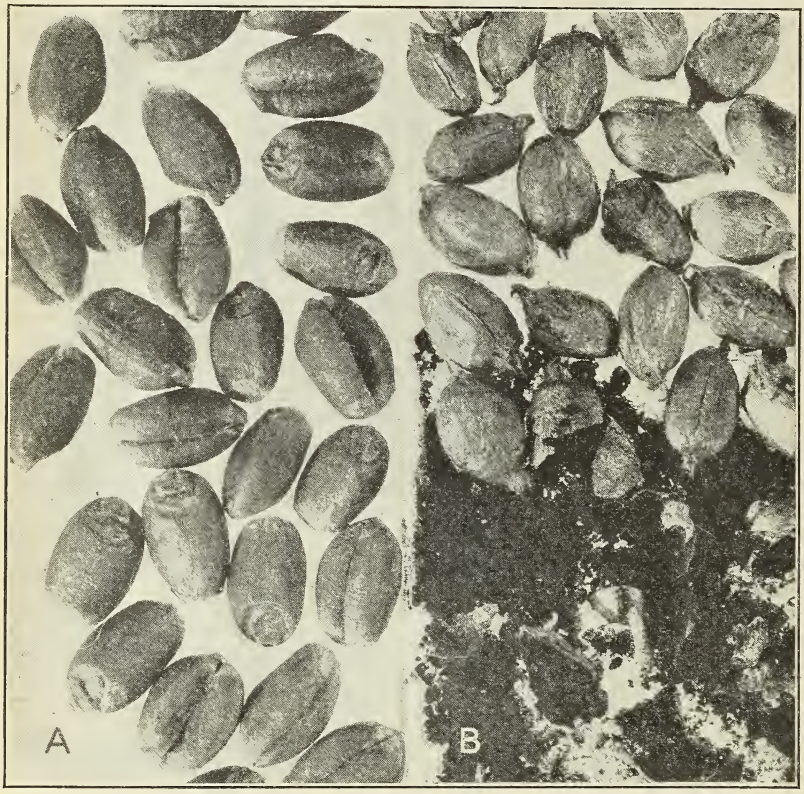

FIGURE 3.—Normal kernels (A) and smut balls (B) of wheat. Some of the smut balls have been crushed to show the powdery contents. × about 5

Stinking smut usually can be prevented by sowing smut-free seed, or by carefully cleaning and treating seed before sowing. It can be reduced by selecting a date of seeding which experience has shown gives the least smut and at the same time is best adapted for the locality, or by sowing varieties resistant to stinking smut.

SMUT-FREE SEED

Smut-free seed can be obtained from a field that is known to be free from any smutted heads. The field from which seed is to be obtained should be examined very thoroughly before harvesting by

one familiar with the appearance of stinking smut so that there will be no question of its being smut free. The threshed grain from such fields should also be carefully examined to determine that the grain is entirely free of smut balls and smut spores. Care should then be taken that the smut-free seed will not be contaminated by smutty harvesting or threshing machinery or by being placed in smutty sacks, wagons, bins, or other containers.

Certified seed bought from reliable seedsmen should be (but is not always) smut free.

Owing to the difficulty of detecting slight traces of smut in a lot of seed, and on account of the fact that under certain weather conditions a very slight seed infestation may result in a badly smutted crop, it is usually best to treat the seed and thus insure its freedom from smut. Furthermore, recent research has brought out evidence that yields may be increased by some of the seed treatments even in the absence of stinking smut.

CLEANING AND TREATING SEED

Stinking smut in wheat can be prevented, or at least reduced to a negligible amount, where soil infestation is not a factor, by thoroughly cleaning the seed to remove all smut balls and then properly treating it with one of the recommended fungicides. This has been proved by numerous experiments carried out by the United States Department of Agriculture and by State experiment stations. Results obtained in experiments in 1929 and 1930 with three spring-wheat varieties are shown in Table 2. The wheat used in these experiments was thoroughly cleaned so that all smut balls were removed. Powdered smut was then added to the seed so that it was dark with spores and undoubtedly more heavily smutted than seed commonly used in farm practice. Portions of this lot of seed were then treated with Ceresan,[5] copper carbonate (50 per cent brand), copper carbonate (18 per cent brand), and formaldehyde, and sown in plots on the experiment station farms at St. Paul, Minn.; Brookings, S. Dak.; Fargo, N. Dak.; Dickinson, N. Dak; and Bozeman, Mont.

TABLE 2.—*Stinking smut in three varieties of spring wheat grown from seed, which after being thoroughly cleaned of smut balls was heavily smutted, treated as shown, and sown in plots at St. Paul, Minn., Brookings, S. Dak., Fargo, N. Dak., Dickinson, N. Dak., and Bozeman, Mont., along with smutty untreated seed for comparison*

Seed treatment	Rate per bushel	Smutted heads										Control
		Prelude, 1929 crop		Kota				Ceres, 1930 crop		Total		
				1929 crop		1930 crop						
	Ounces	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Per cent*
Untreated check	-------	3,270	36.95	2,274	20.8	385	6.95	832	13.22	6,761	21.38	------
Ceresan	2	135	1.53	77	.70	24	.45	80	1.29	316	1.01	95.3
Copper carbonate, 50 per cent brand	2	21	.24	37	.34	5	.09	8	.13	71	.23	98.9
Copper carbonate, 18 per cent brand	2	37	.42	61	.55	8	.15	29	.48	135	.43	98.0
Copper carbonate, 18 per cent brand	3	-------	-------	-------	------	5	.09	5	.08	[b]10	[b].09	[b]99.6
Formaldehyde	[a]	5	.06	8	.07	0	0	0	0	13	.04	99.8

[a] Dipped in 1:320 formaldehyde solution 15 minutes and covered 2 hours.
[b] Not comparable, being only one year's results.

[5] An ethyl mercuoy chloride dust disinfectant.

In the 1929 experiments formaldehyde reduced the percentage of smut to a small trace, and in 1930 it prevented smut entirely. The 50 per cent brand of copper carbonate applied at the rate of 2 ounces per bushel reduced the percentage of smut in every case to less than one half of 1 per cent. The diluted brand of copper carbonate, containing only 18 per cent copper, when used at the rate of 2 ounces per bushel, was not as effective as the 50 per cent brand, but at 3 ounces per bushel it was as good as, and in some cases better than, the 50 per cent brand applied at the 2-ounce rate. In these experiments Ceresan, on the whole, was less satisfactory in the control of smut than the other treatments.

Numerous other experiments could be described to demonstrate the fact that, where soil infestation does not occur, stinking smut can be prevented by properly cleaning and treating the seed. Unsatisfactory results obtained on farms usually can be traced to improper cleaning or treating. Therefore the two most important factors in smut prevention are properly cleaning and treating the seed.

METHODS OF CLEANING SEED

The proper preparation of seed wheat requires that it be thoroughly cleaned before treating for smut control. Practically all wheat as it comes from the threshing machine contains more or less weed seeds, other grains, and foreign material. When the wheat is smutty it also usually contains a considerable number of whole and broken pieces of smut balls as well as smut spores. The wheat also frequently contains a considerable percentage of diseased kernels that are shrunken in size and of light weight.

The 1929 crop of wheat produced and delivered to country elevators in the spring-wheat States contained readily separable weed seeds, other grains, and foreign material (dockage), in the following average percentages by weight: Montana, 1.9; South Dakota, 3.2; Minnesota, 4.2; and North Dakota, 5.5. The wheat also contained a certain quantity of foreign seeds and smut balls which were not separated from the grain with the testing equipment used at the elevators, and in addition to this, much of the wheat had been rid of other material by being cleaned on the farms before it was delivered to the country elevators. From this it will be seen that the wheat delivered from the threshing machines in that area contained considerable quantities of foreign seeds and smut balls. Wheat produced in other areas also contains varying but usually smaller amounts of foreign seed. Weed seeds planted with the wheat will produce weeds in the fields. Weeds materially reduce the wheat yield, and the weed seeds that are harvested with the wheat cause a reduction in the price that is paid for the wheat when it is sold on the market.

All but a fraction of the weed seeds and other foreign material and smut balls can readily be removed from the seed wheat by means of the modern grain-cleaning machinery that is available. Several types of cleaning machines are adapted for cleaning seed wheat as well as for cleaning grain to be sold on the market. The most efficient types of cleaners employ air in connection with sieves, indented surfaces in disks, or drums, or angle screens.[6]

[6] BLACK, R. H., and BOERNER, E. G. CLEANING GRAIN ON FARMS AND IN COUNTRY ELEVATORS. U. S. Dept. Agr. Farmers' Bul. 1542, 27 p., illus. 1927.

For cleaning seed wheat it is essential for efficient results that a heavy current of air be forced or drawn through a thin layer of the grain as it passes through the cleaner, in order to remove whole and broken pieces of smut balls and many of the smut spores, lightweight kernels of wheat which are usually diseased, lightweight weed seeds, and other foreign materials. (Fig. 4.) After the lightweight material has been removed by air, foreign seeds that are larger or smaller in diameter than the wheat kernels can be taken out by means of screens, and the foreign seeds that are either shorter or longer than the wheat kernels can be removed by means of indented disk or cylinder types of cleaners. Foreign seeds that are longer than the wheat kernels can also be removed by angle screens. Spiral surface machines will remove round seeds. Smut balls are usually small in size and somewhat lighter in weight than the wheat in

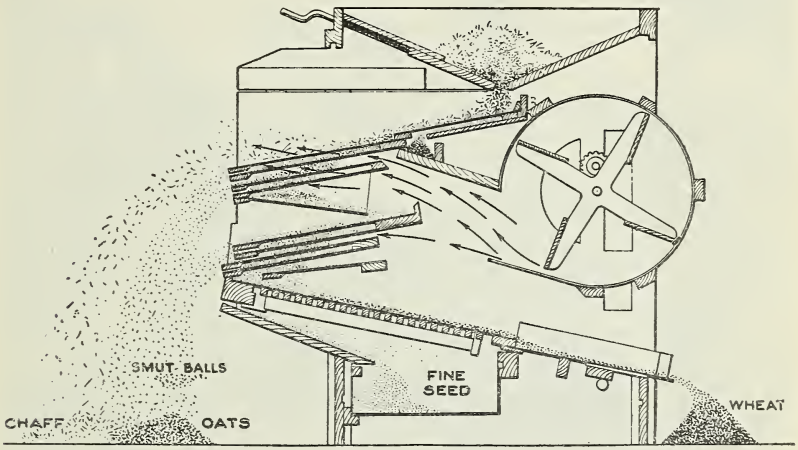

FIGURE 4.—Cross section of farm fanning mill in operation

which they are found, and for this reason they can be efficiently removed from the wheat by means of any of the grain-cleaning machines that employ a strong air blast or suction along with the other cleaning features of its particular type or design.

The various types of cleaning machines are designed for either farm or country elevator use. Those that are designed for country elevator use are of large capacity and are usually somewhat more efficient for thorough cleaning. Many country elevators are equipped to clean farmers' seed grain, and much seed wheat is cleaned in this manner.

In some areas farmers have established centralized community seed-cleaning plants. The advantage of such plants is that the more expensive types of efficient cleaners or combinations of cleaners can be installed at a low cost to each farmer member. In some areas itinerant portable cleaning outfits have come into use for custom cleaning. Many farmers who have purchased efficient high-cost cleaners principally for their own use have installed such cleaners on trucks or trailers and are doing itinerant cleaning for other farmers during the slack season on the farm.

In late years since smut infection has become widespread a number of farming communities have equipped themselves with portable combination seed-cleaning and smut-treating machines which are moved from farm to farm where cleaning and treating are performed at a given charge per bushel.[7] (Fig. 5.)

Another way of cleaning seed wheat is by the flotation method. A number of the commercial types of formaldehyde-treating machines have been so designed that smut balls are removed from the wheat at the time it is treated with the liquid solution. (P. 15 and fig. 9.) In these machines the wheat is fed into the liquid solution in a thin stream. The wheat kernels are heavier than the solution and sink to the bottom, while the smut balls, wild oats, and other

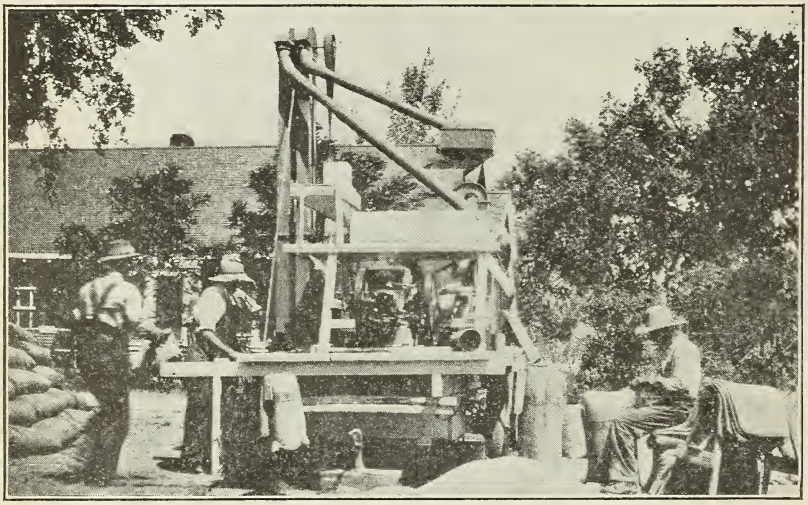

FIGURE 5.—Portable combination cleaning and dust-treating outfit at work

weed seeds lighter than the solution float on the surface, from which they are automatically removed. In homemade formaldehyde-treating machines the smut balls which float on the surface of the liquid can be skimmed off by hand by means of a scoop made from a screen. A further discussion of the formaldehyde treatment and the types of equipment used in applying it will be found on pages 14 to 16.

METHODS OF TREATING SEED

After the wheat has been thoroughly cleaned it is ready to be treated, unless both the cleaning and treating have been done in one operation by a portable combination cleaning and treating machine, at a centralized plant, or in a formaldehyde machine.

There are two chief methods of treating seed now in common use—the dry or dust method and the wet or formaldehyde method.

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[7] MEIER, F. C., BOERNER, E. G., BODNAR, G. P., LEIGHTY, C. E., and COKE, J. E. THE COMBINATION CLEANING AND TREATING OF SEED WHEAT. U. S. Dept. Agr. Leaflet 33, 8 p., illus. 1929.

THE DRY METHOD

The most widely used dust fungicide, and, on the whole, the most satisfactory one, is copper carbonate containing about 50 per cent metallic copper. It should be fine enough to pass through a 200-mesh sieve when suspended in water and should be light green in color. There are also on the market diluted forms of copper carbonate containing 18 to 30 per cent of metallic copper. To be equally effective these should be used at a heavier rate than for the pure 50 per cent copper carbonate. There also are other dusts with various trade names, but none of these has been found to be more effective than pure copper carbonate when used at the same rate per bushel of seed. For effective results the 18 per cent copper carbonate should be applied at about 3 ounces per bushel of wheat, and the 50 per

FIGURE 6.—Homemade barrel duster

cent copper carbonate at about 2 ounces per bushel, and the copper carbonate containing intermediate percentages of metallic copper should be applied in like proportion.

Copper carbonate, or any other fungicidal dust used, should always be applied to wheat with a machine that thoroughly coats every kernel with the dust. Do not try to apply the dust to the seed by mixing it on the barn floor with a shovel or by stirring it by hand in the drill box. These methods will result in failure to control smut, because each kernel will not be thoroughly covered with the dust.

The most common type of dusting machine used on the farm is the homemade barrel duster shown in Figure 6. The advantages of this type are that (1) it is easy to make and inexpensive, and (2) it is very effective if properly used. Its chief disadvantage is that

with two men operating it, it is capable of treating only 15 to 20 bushels per hour and is therefore unsuitable for the farmer who has a large acreage of wheat to sow. With this machine it would take about a week to treat enough seed for 1,000 acres. Unsatisfactory results are often obtained with the barrel mixer because it is turned either too fast or not long enough. About 30 revolutions per minute for two minutes will dust the seed thoroughly. Poor results are also caused by dusting too large a batch. The volume of the batch should not exceed one-fourth to one-third of the space inside the mixer. Directions for making a barrel duster may be obtained from almost any State experiment station or from the United States Department of Agriculture.[8]

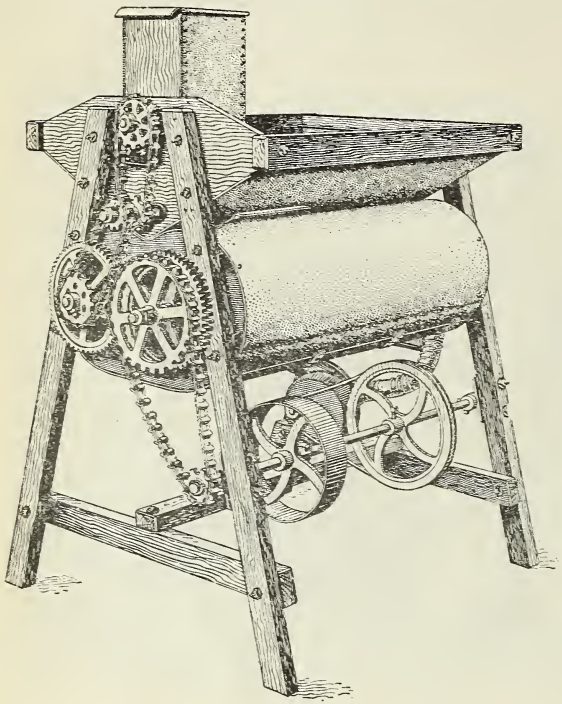

FIGURE 7.—Power duster of the stationary-cylinder type, capable of treating 150 bushels or more per hour

For treating larger quantities of seed there are on the market a number of commercial power dusters with capacities of from 30 to 200 bushels of wheat per hour. (Fig. 7.) Some of these can be combined with a power cleaner so that both operations may be performed at once. When this is done sometimes the capacity of the cleaner is greater than that of the duster. This overloads the latter and causes poor coverage. This difficulty can be overcome, however, by feeding the grain into the cleaner only as fast as it can be properly treated in the duster. Seed that is well dusted with copper carbonate is of a uniform greenish gray color and is not "spotty." Poorly dusted seed is likely to produce a smutty crop.

Commercial treaters usually are of the continuous kind; that is, continuous streams of seed and dust in the right proportions are fed into the treater at one end, they are mixed passing through, and the dusted seed runs into a sack at the other end. These continuous treating machines are of three general types—the revolving-cylinder type, the stationary-cylinder type, and the gravity type.

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[8] TAPKE, V. F., and MEIER, F. C., COPPER-CARBONATE SEED TREATMENT FOR STINKING SMUT OF WHEAT. U. S. Dept. Agr. Misc. Circ. 108, [4] p., illus. 1928 (rev.).

The revolving-cylinder type consists of a slightly oblique revolving cylinder, usually with longitudinal and transverse baffle plates inside. The wheat and dust enter through a central opening in the higher end, are thoroughly mixed by the revolving cylinder together with the action of the baffles, and the dusted wheat is caught in sacks at the lower end.

In the stationary-cylinder type the wheat and dust are drawn through the cylinder and mixed by a revolving auger or mixing device.

In the gravity type the wheat and dust enter at the top of a vertical chute. Sloping baffle plates project the wheat from one side to the other as it descends, thus mixing it with the dust by the time it reaches the bottom, where the dusted grain flows directly into a sack.

Modifications of each type are numerous, such as the use of elevators to elevate the grain to the hopper, screens to remove the excess dust, vacuum fans to prevent the dust from escaping into the room, and blowers to feed the dust into the mixer. The proper type to be used on any farm will depend on its relative cost, capacity, efficiency, expense of operation, and its adaptation to the cleaning equipment in use on that particular farm.

FIGURE 8.—Simple apparatus for applying the formaldehyde-soak method of treatment to small quantities of seed

Caution. — In treating wheat with copper carbonate or any other fungicidal dust it should be remembered that these dusts are poisonous and therefore harmful to man and animals. When treating seed or handling dusted grain a dust mask should be worn to prevent inhaling the dust, as severe nausea and vomiting are often caused from so doing. Dusted grain should not be fed in quantities to farm stock nor on any account sold to mills for making flour or feed.

Where grain can be thoroughly cleaned and treated for a reasonable charge at a central well-equipped cleaning and treating plant, this means of preventing smut can be employed unless there is danger of mixing varieties or unless transportation is too great a factor. In some sections of the country, as previously stated, portable combination cleaners and dust treaters which go from farm to farm have been very successful. (Fig. 5.)

THE WET METHOD

Formaldehyde is the liquid most commonly used in the wet treatment, although copper sulphate (bluestone) continues to be employed to a slight extent.

Smut balls must be removed from the seed before or during treatment with formaldehyde in order to secure any considerable degree of success in smut prevention. The oily material of the smut balls is not penetrated by the formaldehyde solution, and therefore the spores in them are not killed by it. In the handling and drilling of the grain after treatment many of these smut balls, if they are permitted to remain in the grain, are broken, and the seed grain again becomes infested with viable smut pores. Treating with formaldehyde does not protect the grain from recontamination, as is the case to some extent with dust fungicides. Therefore, all smut balls must be removed from the seed wheat, and the treated seed must be placed in clean or disinfected sacks to prevent contamination.

There is only one thoroughly effective general way of treating smutty wheat with formaldehyde, and that is by soaking the seed in open containers and removing the smut balls as they float to the surface of the formaldehyde solution. This may be done by soaking the seed in tubs or troughs, or by using machines that remove smut balls.

Sprinkling or spraying, or dipping the seed in sacks, or treating in machines that do not remove smut balls, as a rule does not give satisfactory results.

For small lots of seed two wooden tubs fitted with handles can be used. (Fig. 8.) One or both tubs should have a hole about 2 inches in diameter at the bottom of one side, covered with a screen and fitted with a plug. Fill the treating tub about two-thirds full with a 1:320 formaldehyde solution made by pouring one-half pint of commercial formaldehyde into 20 gallons of water (1 pint to 40 gallons). Pour the smutty wheat slowly into the solution; stir thoroughly until all smut balls, light and worthless kernels, chaff, and other trash have risen to the surface. Skim off this material. After the wheat has been in the solution for 8 to 10 minutes, drain off the liquid into the other tub and treat another batch. The treated grain should be spread out in a thin layer on a clean floor or canvas and allowed to dry sufficiently so that it will flow through the drill, and should then be sown at once.

For somewhat larger lots of seed a tight trough set on sturdy sawhorses or on a platform will be found useful. The trough should be filled about two-thirds full with the formaldehyde solution (1 pint to 40 gallons of water). Pour in the wheat seed, stir thoroughly, skim off the smut balls, and soak 8 to 10 minutes. Draw off the liquid and shovel out the treated grain on the floor or canvas, or remove the grain directly from the liquid with a specially prepared homemade screen shovel, scoop, or wire basket.

For the farmer who has a rather large acreage to sow and who wishes to use the formaldehyde treatment, or for those who wish to avoid the slow and laborious task of treating large quantities of wheat by hand, there are on the market treating machines which can be obtained at reasonable prices. The purchaser of such a machine, however, should be certain that, among other things, it satisfies these two requirements: (1) That it thoroughly wets every kernel with formaldehyde, and (2) that it causes the smut balls, light seeds, trash, etc., to float to the surface, where they are skimmed off. Some of the formaldehyde machines on the market fail to remove the smut

balls and so should not be used for wheat unless the seed has been thoroughly cleaned beforehand to remove smut balls.

Three general types of formaldehyde-treating machines are in use, known as the floating-out type, the auger type, and the automatic-sprinkle type.

In the floating-out type (fig. 9) the seed drops into the solution tank from the hopper. The smut balls and light material rise to the surface and are removed automatically. The sound seed sinks to the bottom of the tank from which it is elevated out into sacks or a wagon box. This seems to be a very satisfactory type of machine.

With the auger type, the wheat is emptied into a large hopper. The bottom layers are wet in the solution contained in a receptacle below and then elevated out by an auger or screwlike arrangement operated either by hand or by power. The chief objection to these machines

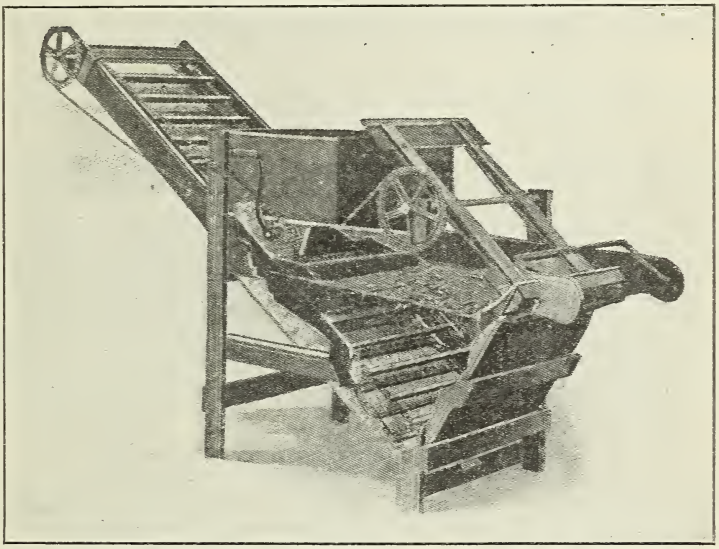


FIGURE 9.—Formaldehyde-treating machine of the floating and skimming type, capable of handling about 50 bushels per hour

is that there is no chance for the smut balls to rise to the surface of the solution and be removed. They are imprisoned at the bottom of the pile and carried out with the treated seed.

The automatic-sprinkle type is popular, probably because of its simplicity and low cost, as well as ease and rapidity of operation. The seed is shoveled into the hopper and runs slowly out at the bottom, where it strikes the blades of a propellerlike part, setting it in rotation. The formaldehyde solution, in another receptacle, is allowed to escape by gravity through a rubber tube and a stopcock and also impinges on the rotating disk. The whirling seed is thoroughly wet with the solution and falls into a receptacle or on the floor below. It will be noted that this is essentially a sprinkling treatment. It is not a soaking treatment. There is no chance for the smut balls to be removed, and so this type of machine can not be thoroughly effective in smut control unless the smut balls have been removed by a thorough cleaning of the grain beforehand.

Caution.—If the seed is to be treated with formaldehyde, the following precautions must be taken: (1) Be sure that the formaldehyde solution used is of the proper strength. If too strong, it will injure the seed; if too weak, it will not control the smut. The formaldehyde itself should be obtained from a reliable source. (2) Do not delay sowing too long after treating. The treating should be done the same day the seed is sown, or not sooner than the afternoon of the day preceding sowing. Otherwise the seed will dry too much, causing the formation of paraformaldehyde, which injures the seed germ and causes a poor stand. (3) Do not sow formaldehyde-treated seed in soil that is too dry to bring about immediate germination, for the same reason stated in 2. Under such conditions it is advisable to treat with copper-carbonate dust instead of formaldehyde. (4) In sowing formaldehyde-treated wheat the drill should be set to sow 1 peck more per acre than when untreated wheat is sown. This allows for the greater volume due to the swollen condition of the treated seed.

WHY TREATMENTS SOMETIMES FAIL TO CONTROL SMUT

During the summer of 1930 a survey was made to find out more about the prevalence of smut in spring wheat and the seed-treatment practices followed by the farmers. Of the 704 wheat fields examined in the spring-wheat areas of Minnesota, the Dakotas, and Montana, 434, or about two-thirds, of the fields had been sown with treated seed. The fields from treated seed showed an average of 2 per cent smut infection and the fields from untreated seed just double that amount, or 4 per cent. There was, of course, considerable variation in the percentage of smut in different fields both from treated and untreated seed. The infection in the fields from untreated seed varied from no smut to as high as 52 per cent. In the fields from treated seed it varied from no smut to 48 per cent. The higher percentages of smut doubtless were contingent on the degree to which the seed was infested. The low average percentage of smut in the fields from both the treated and the untreated seed was due to the fact that in many cases the seed had been almost smut free.

The question at once arises, "Why so much smut in fields from treated seed?" If the seed treatments had been properly applied there should have been none or only a trace of smut in fields from treated seed. Many of the fields from treated seed were practically smut free, but others showed high percentages of smut. One of the smuttiest fields found in the survey was a field of Marquis, the seed for which was said to have been treated with formaldehyde applied by the sprinkle-and-shovel method. It showed 48 per cent smut. Another treated field showed 33 per cent and still another 31 per cent.

A study was made of the different methods of seed treatment that had been used, and it was found that more than half of the growers who treated their seed were not following the right methods. They were not giving enough attention to cleaning the seed to remove smut balls; they were applying formaldehyde by sprinkle-and-shovel methods; and a surprisingly large number were trying to get results with copper carbonate or other dusts by mixing the grain and dust with a shovel or rake.

Figure 10 shows the relative effectiveness of the different methods found in use. Aside from the hot-water and blue vitriol (copper sulphate) treatments, only three instances of which were observed, the most effective treatments were the copper carbonates (both the 50 and 20 per cent grades), formaldehyde, and Ceresan, all applied with machines. These same chemicals when applied by the sprinkle-and-shovel methods or their equivalents usually were unsatisfactory. Spring-wheat growers should abandon the latter methods (fig. 10) and use only the better methods, which have proved effective.

The relative effectiveness of the different methods in the case of 110 fields of Montana winter wheat is also given. (Fig. 11.) The results in general agree with those for spring wheat and with what might be expected, namely, that—

(1) The formaldehyde sprinkle and shovel method, and also the formaldehyde dip method, whereby a sack containing about a bushel of seed is dipped in a barrel or tub for a few minutes, are decidedly unsatisfactory for smut control. They do not remove smut balls.

(2) The blue-vitriol method did not control for similar reasons.

(3) Formaldehyde applied with a good commercial machine is the best liquid treatment.

(4) Dust treatments can not be made successfully by the sprinkle and shovel method.

(5) The dust treatments gave the best control of any of the treatments when applied with good commercial machines or home mixers.

The removal of smut balls seems to be the most important detail that is being neglected. In the case of the liquid formaldehyde treatment it has always been recommended that the smut balls be removed by cleaning or by soaking in the formaldehyde solution and skimming off the smut balls as they rise to the surface. The sprinkle-and-shovel method of applying formaldehyde is all right for oats, but not for wheat unless it is definitely known that the seed is free from smut balls.

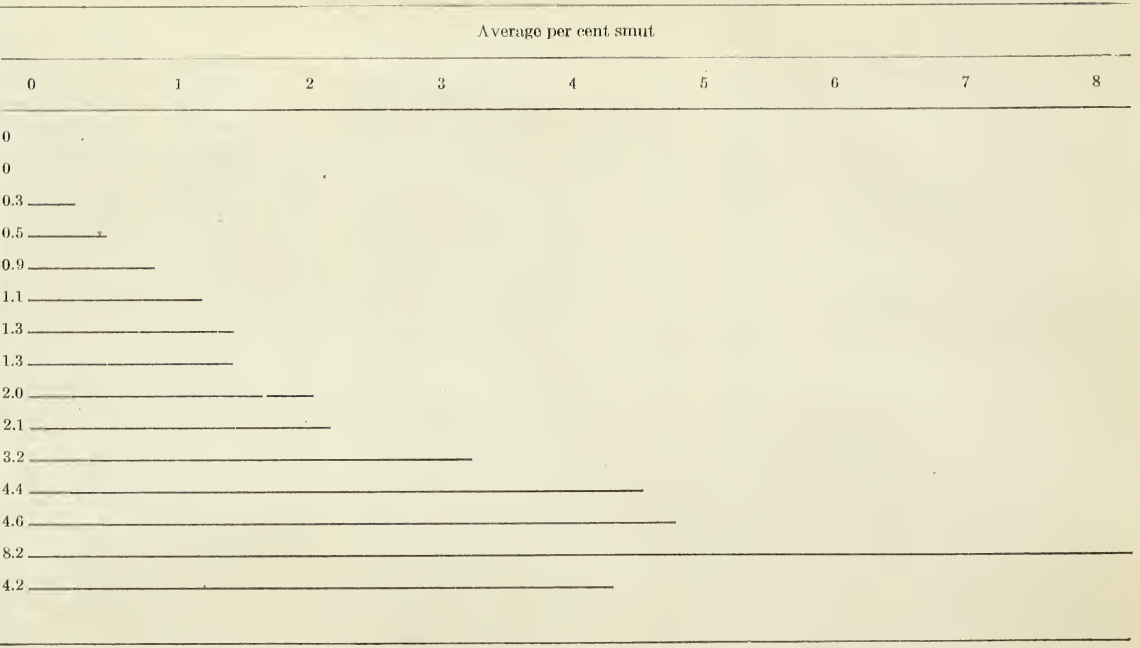
TREAT WHEAT SEED EVERY YEAR

Annual seed treatment is cheap insurance against smut. For a few cents enough copper carbonate or formaldehyde can be purchased, which, if properly applied, will insure a clean crop in regions where soil infestation does not occur.

Soil infestation is likely to occur in certain of the Western and Pacific Coast States where there is no rainfall between harvesting-threshing operations and the date of winter-wheat seeding. In those areas it is sometimes an important factor in the case of fall-seeded wheat, but not in the case of spring wheat. In most of the country, however, there is no soil problem, and seed infestation is the only source of smut to be guarded against.

Those who do not treat every year run the risk of heavy losses. Even a slight amount of smut on the seed can result in a large amount in the crop under certain weather conditions. Threshing machines are known to spread smut, so that although a farmer's fields are clean this year they may not be next. It is too common a practice to treat every other year or only when necessary; but who can tell definitely when it may be necessary? Even experts have difficulty in detecting slight traces of smut in the grain.

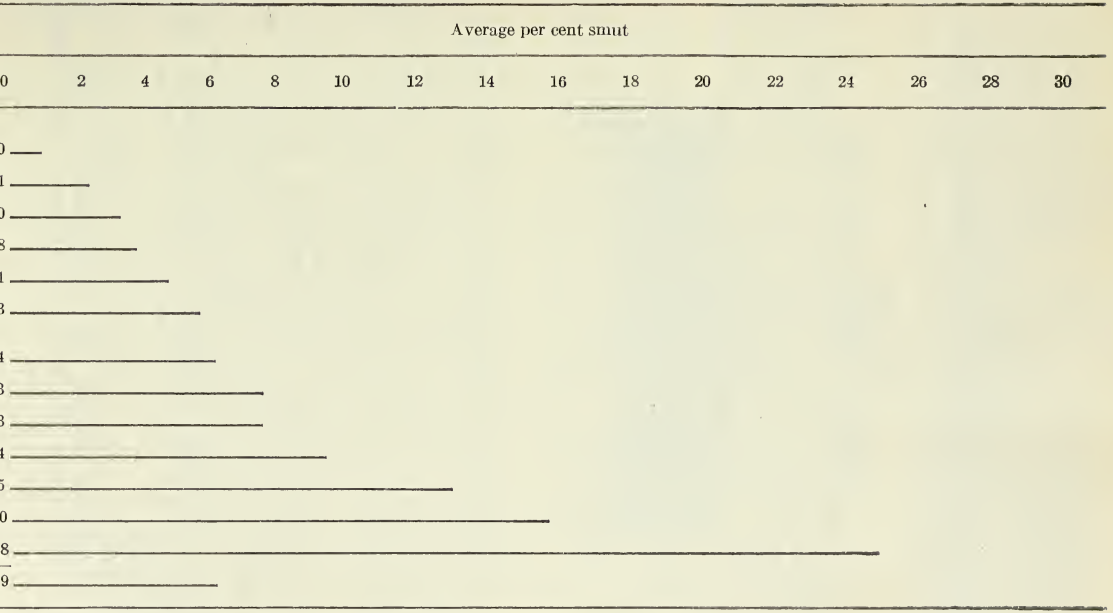
Treatment	Number of fields	Average per cent smut
Hot water	2	0
Blue vitriol (copper sulphate)	1	0
50 per cent copper carbonate (machine)	11	0.3
20 per cent copper carbonate (machine)	9	0.5
Formaldehyde (machine)	93	0.9
20 per cent copper carbonate (home mixer)	33	1.1
Ceresan (machine)	17	1.3
Ceresan (shovel)	7	1.3
Formaldehyde (dip)	20	2.0
Formaldehyde (sprinkle)	196	2.1
50 per cent copper carbonate (shovel)	6	3.2
Formaldehyde (spray)	6	4.4
20 per cent copper carbonate (shovel)	24	4.6
20 per cent copper carbonate (mixed in drill)	1	8.2
No treatment [1]	270	4.2
Total	696	



[1] In many cases relatively clean seed was responsible for no treatments being used, hence the low average percentage of smut from untreated seed.

FIGURE 10.—Relative effectiveness of different methods of spring-wheat seed treatments in 1930

Treatment	Number of fields	Average per cent smut
50 per cent copper carbonate (method not given)	1	1.0
50 per cent copper carbonate (homemade mixer)	16	2.1
50 per cent copper carbonate (commercial machines)	30	3.0
20 per cent copper carbonate (method not given)	2	3.8
Ceresan (homemade mixer)	3	4.1
Formaldehyde (commercial machines)	2	5.3
Blue vitriol (copper sulphate) (sprinkle and shovel)	3	5.4
Blue vitriol (soak)	7	7.3
50 per cent copper carbonate (shoveled)	4	7.3
Formaldehyde (sprinkle and shovel)	24	9.4
20 per cent copper carbonate (commercial machines) [1]	8	12.5
Formaldehyde (dip)	1	15.0
No treatment	9	24.8
Total or average	110	5.9



[1] These 8 fields include the 1 field that showed 54 per cent, the most smut in the entire survey.

FIGURE 11.—Relative effectiveness of different methods of seed treatment in 110 fields of Montana winter wheat, 1929–30

In localities where the disease is common and frequently destructive it will pay to be on the safe side and treat every year.

In the spring-wheat survey referred to above one of the questions asked growers was, "Do you treat wheat every year?" The answers showed that in 1930 those who make it a practice to treat every year had on an average 1.4 per cent smut, while those who treat every other year or only when necessary had on an average 4.7 per cent.

SUMMARY

Stinking smut (bunt) is one of the most common and important diseases of wheat. It is estimated that some 18,000,000 bushels of wheat are lost annually in the United States because of reduced yields due to smut. Eleven and one-half per cent of the 1929 crop that was inspected was graded smutty at the terminal markets and was sold at discounts.

Numerous experiments have shown that stinking smut can be prevented or reduced to a negligible amount in most parts of the country by thoroughly cleaning seed to remove the smut balls and then properly treating it with copper carbonate or formaldehyde, preferably the former, as it does not reduce germination and has other advantages.

If copper carbonate is used, 2 ounces of the 50 per cent grade or 3 ounces of the 18 to 20 per cent grade should be applied to each bushel of seed with a commercial or homemade machine so that the dust thoroughly covers every kernel. On no account should an attempt be made to apply copper carbonate by shoveling or raking methods.

If formaldehyde is used, the seed should be soaked in a solution made up of 1 pint of commercial formaldehyde to 40 gallons of water, using containers or machines which float smut balls to the surface where they can be skimmed off. Some machines do not remove smut balls. The sprinkle-and-shovel method of applying formaldehyde usually is ineffective, as it does not remove smut balls.

A field survey of spring wheat in 1930 showed that many farmers were not using the proper methods of seed treatment nor giving enough attention to the details of treatment and so were not getting satisfactory results.

To control stinking smut, treat the seed regularly, carefully, and thoroughly, following closely the directions for the approved methods, and using the right kinds of apparatus and reliable materials.

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